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Charles W. Stewart

Date: 1 April 2005

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	
RASHMI K. SHAH et al.	
Serial No. 09/168,770	Group Art: 1764
Filed October 8, 1998	Examiner: Basia A. Ridley
FLAMELESS COMBUSTOR PROCESS HEATER	

COMMISSIONER FOR PATENTS
P. O. Box 1450
Alexandria, VA 22313-1450

Sir:

APPELLANT'S BRIEF

This brief is filed in support of Applicant's appeal from the Examiner's action dated November 2, 2004, finally rejecting claims 1-7, 14-18 and 20-24, which are all of the claims remaining in the above-identified U.S. patent application. A notice of appeal was filed by Applicant on February 3, 2005.

Please charge the fee for filing this brief (which is being filed in triplicate) to Shell Oil Company Deposit Account No. 19-1800.

It is respectfully requested that the Board reverse the final rejection of claims 1-7, 14-18 and 20-24 of the above-identified application for the reasons discussed below as supported by the cited authorities.

REAL PARTY IN INTEREST

The invention described and claimed in the above-identified patent application is assigned to Shell Oil Company, which is the real party in interest in the present appeal.

RELATED APPEALS AND INTERFERENCES

Appellant and Appellant's legal representatives, are not aware of any appeals or interferences that directly affect or could be directly affected by or have a bearing on the Board's decision in the present appeal.

STATUS OF CLAIMS

This appeal involves claims 1-7, 14-18 and 20-24.

Claims 8-12 are withdrawn from consideration as not directed to the elected invention.

Claims 13 and 19 have been canceled.

STATUS OF AMENDMENTS

Appellant proposed several amendments to the claims in Appellant's response after final rejection. However, these were refused entry by the Examiner on the grounds they raised new issues that would require further consideration and/or search. Thus, the claims involved in this appeal are the claims which were in the application at the time the of the final Office action of November 2, 2004. A copy of these claims is contained in Appendix A.

SUMMARY OF THE INVENTION

The present invention relates to a flameless distributed combustion process heater apparatus for providing heat to endothermic chemical reactions at a desired temperature profile and a controlled heat flux at a sufficiently high rate to complete the endothermic chemical process being conducted in the process chamber of said process heater apparatus. The flameless distributed combustion process heater apparatus of the present invention comprises three basic elements:

(1) An oxidation chamber containing a fuel conduit with a plurality of nozzles distributed along substantially the entire length of the oxidation chamber. The nozzles are spaced to produce combustion without a flame (i.e., "flameless" combustion) when fuel is mixed with preheated oxidant in the oxidation chamber.

(2) A preheater for heating oxidant to a temperature that when the oxidant and fuel are mixed in the oxidation chamber, the temperature of the resulting mixture will exceed the autoignition temperature of said mixture.

(3) A process chamber in a heat exchange relationship with the oxidation chamber whereby a controllable heat flux is provided to the process chamber at a sufficiently high rate to complete the process being conducted therein.

Various endothermic chemical reactions such as the steam reforming of hydrocarbons, dehydrogenation of ethyl benzene to produce styrene, and the like, can be conducted in the process chamber.

The spacing of the fuel nozzles and the distribution of the fuel nozzles along substantially the entire length of the oxidation chamber results in flameless, distributed combustion in the oxidation chamber, which provides a controllable heat flux to the process chamber at a sufficiently high rate to complete the process being conducted therein. The heat flux may be controlled to provide a uniform temperature profile, but can also provide increasing or decreasing temperature profiles. (Specification, page 6, lines 9-13).

A basic advantage of the present invention is that the temperature profile, or flux of heat, may be controlled to whatever temperature profile is desired for a particular reaction. (Specification, page 6, lines 12-13) The benefits of the flameless distributed combustion process heater of the present invention include higher temperatures within metallurgical constraints, improved conversions, improved selectivities and/or product yields, reduced by-product production, reduced risk of tube failures due to "hot spots", lower energy consumption and low NO_x emissions. (Page 4 of specification, line 26, to page 5, line 9.)

The specific limitations being relied on to distinguish over the cited references include the limitations that "a plurality of fuel nozzles" be distributed "along substantially the entire length of the oxidation chamber", that the fuel nozzles are "spaced so that the fuel is added to the oxidation chamber at a rate that no flame results when fuel is mixed the oxidant" in the oxidation chamber, and that "a controllable heat flux is provided to the process chamber at a sufficiently high rate to complete the process being conducted therein". These limitations are included in independent claim 1 and the claims depending there from.

Claim 18, the only other independent claim, and the claims depending there from, contain the limitations that the fuel conduit contain "a plurality of fuel nozzles distributed along substantially the entire length of the oxidation chamber", that the fuel nozzles be spaced so that the flow of fuel through the fuel nozzles "results in no flame" when the fuel passes through the nozzles and is mixed oxidant in the oxidation chamber, and that "said plurality of nozzles distributed along substantially the entire length of said oxidation chamber being sized to provide the desired temperature distribution within said process chamber and the heat flux necessary to complete the process being conducted therein" .

ISSUES

Whether claims 1-7, 14-18 and 20-24 are unpatentable under 35 U.S.C. § 102(b) as being anticipated by Ruhl (EP 0 450 872).

Whether claims 1-5, 16-18, 20-21 and 24 are unpatentable under 35 U.S.C. § 102(b) as being anticipated by Mikus (USP 5,255,742).

Whether claims 1-7, 14-18 and 20-24 are unpatentable under 35 U.S.C. §103 (a) for obviousness over Ruhl (EP 0450 872).

Whether claims 6-7, 14-15 and 22-23 are unpatentable under 35 U.S.C. §103 (a) for obviousness over Mikus (USP 5,255,742).

Whether claims 1-7, 14-18 and 20-24 are unpatentable under 35 U.S.C. §103 (a) for obviousness over Ruhl (EP 0450 872) in view of Mikus (USP 5,255,742).

GROUPING OF CLAIMS

Claims 1-7, 14-16, 18 and 20-23 stand or fall together. Claims 17 and 24 do not stand or fall with the other claims, but are believed to be separately patentable by virtue of the limitation that the oxidant flowing through the flow path in the oxidation chamber" is preheated by heat exchange with effluent from the process chamber". This separately patentable embodiment is not taught or suggested by either of the cited references as hereinafter discussed.

ARGUMENTS

In the Office action mailed November 2, 2004, the Examiner finally rejected all of the remaining claims in the application on the basis of two references, Ruhl (EP 0 450 872) and Mikus (USP 5,255,742). Claims 1-7, 14-18 and 20-24 were rejected as anticipated by Ruhl; claims 1-5, 16-18, 20-21 and 24 were rejected as anticipated by Mikus; claims 1-7, 14-18 and 20-24 were rejected as obvious over Ruhl; claims 6-7, 14-15 and 22-23 were rejected as obvious over Mikus; and claims 1-7, 14-18 and 20-24 were rejected as obvious over Ruhl in view of Mikus.

In the following section Appellant will discuss the teachings of the Ruhl and Mikus references taken as a whole. Appellant will then discuss each of the aforementioned rejections in the order they were presented in the Office action of November 2, 2004, with a detailed explanation of why the rejections are erroneous and should be reversed.

The Ruhl Reference Taken as a Whole

Ruhl discloses various apparatuses for effecting endothermic reactions such as reforming light-hydrocarbons (Pg. 4 lines 11-13). The reaction apparatuses of Ruhl include a reaction vessel for effecting an endothermic reaction, having an inlet for feeding the feed gas mixture into the reaction vessel, a discharge for removing product gas, and at least one heat generating means which is enclosed by the reaction vessel and provides heat to the reaction vessel which may contain a catalyst bed (Pg. 3, line 56 to pg. 4, line 1). The heat generating means comprises at least one ceramic combustion tube concentrically surrounding a fuel feed tube which extends at least partially along the length and inside of the combustion tube. The heat generating means has inlets for supplying fuel gas and air. The fuel gas an air are combusted in the heat generating means. The heat which is generated is transferred into the reaction vessel to facilitate the endothermic reaction to produce a product gas (Pg. 4, lines 2-6). Of the various apparatuses depicted in Figs. 1-5 of Ruhl, all except the apparatus depicted in Fig. 4 show combustion with flames. The apparatus in Figure 1, for example, clearly shows a flame in flame zone 50. The apparatus depicted in Fig. 4 does not show a flame and therefore, arguably, utilizes flameless combustion, although the term "flameless combustion" is not used anywhere in the Ruhl reference.

The heat generating means shown in Figure 1 of Ruhl (combustion tube 30), in addition to using combustion with flames, does not have a fuel conduit with a plurality of nozzles. Instead, fuel feed tube 34 (which is located inside of combustion tube 30) has a single opening or nozzle at the end of the feed tube through which the fuel passes, whereupon it is mixed with air and ignited in flame zone 50. (See Fig. 1 of Ruhl).

Since flame zone 50 in Fig.1 of Ruhl is located approximately in the middle of combustion tube 30, it is clear that the temperatures in the lower portion of combustion tube 30 (below the flame zone) and in the upper portion of combustion tube 30 (above the flame zone) will be lower than the temperatures in the flame zone per se. This will result in an uneven or non-uniform temperature profile in combustion tube 30, and correspondingly the provision of an uneven or non-uniform heat flux to packed bed 20.

Lower temperatures in the upper and lower portions of combustion tube 30 are desired by Ruhl because combustion tube 30 is sealed at the ends to plates 16 and 18 by seals 32 (which preferably are low temperature seals such as "a graphite foil spiral wrapped annular cylinder seal") which holds the combustion tube in place. (Pg. 4, lines 39-44). One of the stated advantages of the reaction apparatus of Ruhl is that it "allows for the use of relatively low temperature seals" (Pg. 3, lines 54-55). On page 4, lines 48-49 of Ruhl, it is stated that "A

feature of the present design is that it allows for the use of lower temperature seals where the combustion tube or tubes are joined to the tube sheet."

Of the various apparatuses shown in Fig. 1-5 of Ruhl, only Fig.4 has a feed gas tube with a plurality of perforations or holes 64 which are spaced at intervals along its length in burner zone 68. However, burner zone 68 represents only a minor portion (appears to be roughly 20%) of the overall length of combustion tube 30. Similar to the apparatus in Fig. 1, there are no perforations or holes in the upper or lower portions of combustion tube 30 in Fig. 4. Therefore, the temperatures in these portions will be lower than the temperature in the "burner zone", thus allowing the use of low temperature seals. It is also noted, that the feed gas tube in Fig. 4 has one end plugged or otherwise closed. It is stated in Ruhl "that plug 66 need not resist very hot temperatures and thus could be made of graphite or heat resistant organic cement." (Pg. 5, lines 55-56). This further supports the fact that the upper portion of combustion tube 30 in Fig. 4 (which contains the plugged end of the fuel tube) will have lower temperatures than the middle portion of the combustion tube in which the "burner zone" is located. This will result in the provision of an uneven or non-uniform heat flux to the process being conducted in the reaction vessel, with more heat being provided to section of packed bed 20 surrounding the "burner zone", than to the sections of the packed bed surrounding the upper or lower portions of combustion tube 30.

Thus, neither the heater (combustion tube 30) in Fig. 1 of Ruhl, nor the heater (combustion tube 30) in Fig. 4 of Ruhl is designed to provide an "even" or "uniform" heat flux to the process being conducted in the reaction vessel. Moreover, there is no teaching or suggestion in Ruhl that an "even" or "uniform" temperature distribution is desired. To the contrary, Ruhl teaches that lower temperatures are desired in the upper and lower portions of the combustion tube to allow the use of relatively low temperature seals.

The design of the reactor in Ruhl is said to allow "for a more compact apparatus which can employ a large number and high density of burner tubes" which can operate at high temperatures and pressures. (Page 3, lines 50-52). One design could use 10,000 tubes, each 0.4 inch ID x 0.5 inch OD x 20 feet long. (Page 6, lines 23-24). The use of small-diameter ceramic combustion tubes and graphite seals facilitates a denser packing of burner tubes than previously available in prior art apparatuses. (Page 5 lines 39-40).

The Mikus Reference Taken as a Whole

The Mikus reference discloses a method for injecting heat into a subterranean formation of low permeability, such as diatomites and oil shale, to enhance the recovery of oil (Col.1, lines 9-19). The disclosed heat injection method uses a fuel gas combustor which does not require a flame in the borehole during the heating process (Col. 3, lines 1-5). The absence of flame

eliminates the flame as a radiant heat source and results in a more even temperature distribution throughout the length of the burner (lines 3-5 of the abstract). The disclosed method for heating a subterranean formation requires a borehole from the surface to the subterranean formation and includes the steps of: (1) Combining a hydrocarbon fuel gas with a carbon formation suppressant; (2) passing the fuel gas and carbon formation suppressant mixture through a fuel gas conduit to a mixing point juxtapose to the formation to be heated; (3) passing a combustion air stream through an air conduit to the mixing point; (4) preheating either the fuel gas and carbon suppressant mixture, the combustion air stream or both, such that the temperature of a mixture of the streams exceeds the autoignition temperature of the mixture of streams; (5) combining the preheated combustion air and fuel gas and carbon suppressant at the mixing point resulting in autoignition forming combustion products; and (6) passing the combustion products through the borehole from the mixing point to the surface. (Col. 3, lines 12-36). The heat injectors shown in Figs. 1-5 of Mikus all have in common, a fuel gas conduit 12 having a plurality of orifices 13, an air conduit 10, with the fuel gas conduit and air conduit both being situated in a casing cemented into wellbore using a high temperature cement. The combustion products either travel up the well bore and out an exhaust nozzle at the wellhead as in Figs. 1 and 4, or through a separate combustion gas conduit 19 as in Figs. 2, 3 and 5.

The plurality of orifices in Mikus are sized to accomplish nearly even temperature distribution in the casing. A nearly even temperature profile in the casing results in more uniform heat distribution within the formation to be heated. (Col. 5, lines 46-51).

Mikus teaches that the heat is removed from the combustion chamber of the heat injectors at the relatively low heat flux rate of 375 watts per foot of length. (Col.9, lines 67-68 to col. 10, line 1).

Thus, the apparatus used in the heat injection method of Mikus is designed to inject heat at a relatively low heat flux and a nearly even temperature profile into subterranean formations to uniformly increase the temperature of the formation which causes the oil and water trapped in pores in the formation to expand creating fractures through which the trapped oil can migrate and be recovered.

Regarding the size of the apparatus used in the heat injection method of Mikus, it is taught in column 5, line 23 that the choice of diameter of the casing is a trade off between expense of the casing and the rate at which heat maybe transferred into the formation and that the amount of heat that can be transferred into the formation increases significantly with increasing casing diameter. Mikus further teaches that a casing of between 4 to 8 inches in internal diameter will typically provide an optimum trade off between initial cost and heat transfer. (Col. 5, lines 23-25). Since subterranean formations maybe located hundreds or even

thousands of feet below the surface, the casing containing the fuel gas conduit and air conduit in Mikus could be hundreds or even thousands of feet in length depending on the depth of the subterranean formation to be heated. Only a small portion of the overall length of the feed gas conduit would have fuel nozzles, i.e., the lower portion of the feed gas conduit within the formation to be heated. (Col. 5, lines 41 -43).

While the primary purpose of the heat injection process in Mikus is to create fractures in the formation through which the hydrocarbons can migrate, Mikus does disclose that the injection of heat into a formation may in some cases result in in-situ pyrolysis of hydrocarbons which is an endothermic chemical reaction. More specifically, Mikus discloses in col. 1, lines 36-42, when a formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ, thereby producing products with lower molecular weights which will therefore be more valuable than the original oil. However, there is no disclosure in Mikus of any specific endothermic chemical reactions, or the extent to which the reactions are completed, or what products are produced, other than they are lower molecular weight than the hydrocarbon solids originally trapped in the formation.

Considering the teachings of Mikus as a whole, it is apparent that any such in-situ pyrolysis, if it occurs at all, is incidental to the primary purpose of the heat injection process of Mikus, which is to fracture the formation by thermal expansion of the oil and water trapped within the pores, to allow the hydrocarbons to migrate through the fractures in the formation to a point they can be recovered.

While the apparatus used in the heat injection method of Mikus has an oxidation chamber and uses a preheater to preheat air and/or feed gas, similar to the flameless distributed combustion process heater of the present invention, the apparatus disclosed in Mikus does not have a "process chamber", which is the essential element of the apparatus of the present invention. The porous hydrocarbon-containing subterranean formation which is fractured by the heat injection method in Mikus is an occurrence in nature. It is not an element of the apparatus used in Mikus' heat injection process.

Claim Rejections – 35 U.S.C §102

The rejection of claims 1-7, 14-18 and 20-24 under 35 U.S.C. § 102(b) as being anticipated by Ruhl (EP 0 450 872) is erroneous and should be reversed.

A critical structural feature of the flameless distributed combustion process heater of the invention is that the plurality of fuel nozzles in the fuel conduit be distributed along substantially the entire length of the oxidation chamber. Since the oxidation chamber is in a heat exchange

relationship with the process chamber, the distribution of the fuel nozzles along substantially the entire length of the oxidation chamber allows the provision of a controlled heat by the oxidation chamber to the process chamber at a desired temperature profile and rate of flux, sufficient to complete the endothermic chemical reaction being conducted in the process chamber. This results in improved conversions, product yields, byproduct reduction, etc.

Contrary to the statement on page 2 of the November 2, 2004 Office action, the plurality of fuel nozzles (64) in Fig. 4 of Ruhl, is not "distributed along substantially the entire length of said oxidation chamber (30, 68)". All of perforations or holes 64 in Fig. 4 of Ruhl are spaced only in burner zone 68 which represents only a minor portion (appears to be roughly 20%) of the overall length of combustion tube (oxidation chamber) 30. There are no perforations in the upper portion or the lower portion of combustion tube 30. This uneven distribution of fuel nozzles in the oxidation chamber will result in an uneven temperature distribution in combustion tube 30, with the temperature in "burner zone" 68 of the combustion tube 30 being greater than the temperature in the upper or lower portions of combustion tube. This conclusion is supported by the statement in Ruhl on page 5, lines 55-56, that plug 66, which is at the upper end of fuel tube 60, "need not resist very hot temperatures and thus could be made of graphite or heat resistant organic cement". Based on the location of the perforations in fuel tube 60 in Fig. 4 and the foregoing statement about plug 66, it is clear that Ruhl does not disclose "distributed' combustion, nor would the apparatus in Ruhl be able to achieve the variety of temperature profiles in the process chamber that are achievable in Appellant's apparatus.

Since the fuel nozzles (perforations 64) in Ruhl are not distributed along substantially the entire length of the oxidation chamber, Ruhl does not produce "flameless, distributed combustion throughout said oxidation chamber (Fig. 4)" as stated at the bottom of page 2 of the November 2, 2004 Office action. "Distributed combustion throughout the oxidation chamber" requires fuel nozzles to be spaced along substantially the entire length of the oxidation chamber, which is clearly not taught or suggested in Fig. 4 of Ruhl.

Appellant agrees that claims should be given the broadest reasonable interpretation in view of the specification. However, Applicant submits there is absolutely no reasonable basis to define the oxidation chamber in Ruhl as being only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation chamber in the reaction apparatus in Fig.4 of Ruhl. Combustion tube 30 in the apparatus of Fig.4 of Ruhl runs the full length of the reactor. There are no walls or barriers dividing combustion tube 30 into separate sections or compartments. Oxidant and fuel are free to mix and combust anywhere in combustion tube 30. Hence, it is unreasonable to define the oxidation chamber in Ruhl as being

only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation chamber in the reaction apparatus in Fig.4 of Ruhl.

Since the fuel nozzles (perforations 64) in Ruhl are distributed over only a small portion (about 20%) of combustion tube 30 (i.e., in burner zone 68), Ruhl cannot reasonably be said to meet the limitation in each of the present claims that the fuel nozzles be distributed along substantially the entire length of the oxidation chamber.

Therefore, the rejection of claims 1-7, 14-18 and 20-24 on the basis of anticipation by Ruhl is erroneous and should be reversed, which action is respectfully requested.

Claims 17 and 24 are not anticipated by Ruhl for the additional reason that Ruhl does not disclose preheating the oxidant by heat exchange with effluent from the process chamber. Instead, Ruhl appears to contemplate preheating the oxidant using a conventional commercial preheater. See page 5, lines 44-45, where it is stated: "Although no preheater is illustrated, such devices are known in the art and are commercially available". This statement certainly does not anticipate preheating oxidant using effluent from a process chamber.

In paragraph 11 of the November 2, 2004 Office action, the Examiner makes the argument that Ruhl anticipates claims 17 and 24 because in Fig. 4 the oxidant in oxidant manifold 42 is preheated by heat exchange (heat being transferred by steel plate 16) with the reaction products produced in the process chamber and traveling towards the outlet 24. Appellant does not disagree that some minimal heat exchange might take place between the incoming oxidant in manifold 42 and the reaction products in the process chamber through steel plate 16. However, this disclosure does not anticipate claims 17 and 24 because these claims cover the embodiment wherein the oxidant is preheated with effluent from the process chamber. As known to one skilled in the art, "effluent" is the gas or liquid which emerges from a pipe or similar outlet. The "effluent from the process chamber" in Ruhl is the gas which exits from packed bed 20 (the "process chamber' in Ruhl) through outlet 24. Ruhl does not disclose utilizing the stream exiting the reactor though outlet 24 for preheating the oxidant. Whatever minimal inherent preheating of the oxidant occurs through steel plate 16 is the result of heat exchange with reaction products in the reactor. There is no disclosure using effluent from a process chamber for preheating the oxidant. Hence, claims 17 and 24 are not anticipated by Ruhl for this reason, as well as those discussed above.

Since Appellant is relying on structural limitations to distinguish the present apparatus over Ruhl (e.g., that the plurality of fuel nozzles be distributed along substantially the entire length of the oxidation chamber and that the flameless distributed combustion process heater be configured so that the oxidant is preheated by heat exchange with effluent from the process chamber), and not on statements made in the preamble, nor the manner in which the apparatus

is intended to be used, nor the contents thereof, the rationale of *In re Otto*, 312 F.2d 937, 938, 136 USPQ 458, 459 (CCPA 1963), etc., *Ex parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

The rejection of claims 1-5, 16-18, 20-21 and 24 under 35 U.S.C. § 102(b) as being anticipated by Mikus (USP 5, 255,742) is erroneous and should be reversed.

On page 8 of the November 2, 2004 Office action, it is stated that Mikus discloses:

> "- a process chamber (1) in a heat exchange relationship with the oxidation chamber (Fig. 2-3), whereby a controlled heat flux is provided to the process chamber at a sufficiently high rate to complete the endothermic process being conducted therein (C1/L13-44)".

Appellant does not believe this statement is supported by a reasonable reading of the Mikus reference. Item (1) in Figs. 2-3 of Mikus does not represent a "process chamber". Instead, it represents the "formation to be heated" (Mikus, col. 7, line 45). The "formation to be heated" was not created by Mikus and is not an element of the apparatus used in the heat injection method of Mikus. The "formation to be heated" is a naturally occurring, geological structure located hundreds or even thousands of feet underground, that basically consists of rocky materials which may contain oil and water trapped in the pores of the formation rock. Injection of heat into the formation causes thermal expansion of the water and oil trapped within the pores of the formation rock causing fractures. The hydrocarbons migrate through the small fractures created by the expansion and vaporization of oil and water. (See Mikus col.1, lines 24-36).

Appellant submits it is unreasonable to refer to this fractured, porous structure as a "process chamber". The customary meaning of the term "process chamber" in the chemical process arts is an enclosed space surrounded by walls or other solid structure in which a chemical process is performed. Note that each of the reaction apparatuses depicted in Figs. 1-5 of Ruhl have a process chamber (packed bed 20) with a solid wall (steel shell 20), as do the process chambers 8 in the flameless distributed combustion process heaters depicted in Figs. 1-9 of the present specification. A fractured porous underground formation cannot reasonably be construed to be a "process chamber" as this term is used in the present specification and claims, or in the chemical processing art. While claim terms should be given there broadest reasonable interpretation, the interpretation must be consistent with the specification. *In re Hyatt*, 211 F.3d 1367, 1372, 54 USPQ 2d 1664, 1667 (Fed. Cir. 2000). The interpretation must also be consistent with the interpretation those skilled in the relevant art would reach. *In re Cortright*, 165 F.3d 1353, 1359, USPQ2d 1464, 1468 (Fed. Cir. 1999).

Claims 5 and 20 are not anticipated by Mikus for the additional reason that Mikus does not disclose a process heater with an oxidation chamber capable of providing heat to a process chamber at a rate of flux sufficient to complete the thermal cracking of hydrocarbons to produce olefins. As discussed above, the primary purpose of the heat injection process in Mikus is to enhance oil recovery by heating the entrapped oil to increase its mobility by creating fractures in the formation through which the hydrocarbons can migrate and be recovered (col. 1, lines 1-35). Mikus does disclose that in col.1, lines 36-42, that when a formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ, thereby producing products with lower molecular weights which will therefore be more valuable than the original oil. However, there is no disclosure in Mikus of any specific endothermic chemical reactions, there is no disclosure of the extent to which the reactions are completed and there is no disclosure that olefins are produced. In fact there is no disclosure of any specific products, other than they are lower molecular weight than the high molecular weight oil or hydrocarbon solids originally trapped in the formation.

As would be known to one skilled in the chemical processing arts, the in-situ pyrolysis, which may take place to a limited extent in Mikus, is quite different than the thermal cracking of hydrocarbons to produce olefins, which is one of the endothermic chemical reactions which can be effectively conducted using the present apparatus. As stated on page 14 of the present specification, lines 12-14, the thermal cracking of hydrocarbons to produce olefins takes place at reaction temperatures of 775°C to 950°C and residence times of 0.1 to 0.8 seconds. In contrast to these relatively high reaction temperatures and extremely short reaction times, the heat injection process disclosed in Mikus (and any incidental in-situ pyrolysis) is part of a long term enhanced oil recovery process in which heat at a relatively low rate of flux (e.g., 375 watts per foot) is injected into a formation over a period of months or even years.

Thus, the reaction conditions and environment of the in situ pyrolysis disclosed in the Mikus are quite different than that required for the production of olefins by thermal cracking. Therefore, claims 5 and 20, which are directed to a flameless distributed combustion heater with an oxidation chamber capable of providing heat to a process chamber at a rate of heat flux sufficient to complete the thermal cracking of hydrocarbons to produce olefins, are not anticipated by Mikus.

Claims 17 and 24 are not anticipated by Mikus for the additional reason that Mikus does not disclose preheating the oxidant by heat exchange with effluent from the process chamber. In paragraph 14 of the November 2, 2004 Office action the Examiner makes the argument that Mikus does anticipate claims 17 and 24 because the embodiment in Fig. 2 of Mikus "clearly shows that the oxidant in Oxidant Conduit is preheated by heat exchange (heat being inherently

transferred by the Heat Conductor 7 and Steel Oxidant Conduit) with reaction products produced in at least one process chamber, traveling upwards." The quoted statement reflects a possible misunderstanding of the Mikus heat injection process, which has resulted in an erroneous anticipation rejection.

Contrary to the statement made on page 27 of the November 2, 2004 Office action, the oxidant in Mikus (combustion air) is not preheated by heat exchange with "reaction products produced in at least one process chamber". The heat injector shown in Fig. 2 of Mikus produces heat when preheated air traveling down combustion air conduit 10 is mixed with fuel gas passing through orifices 13 in fuel gas conduit 12 at a temperature above the autoignition temperature of the mixture. The heat generated by the resulting combustion is transferred outward to the formation through cement 7 which is said to be suitable for withstanding elevated temperatures and transferring heat (col. 4, lines 53-56). There is no transfer of heat from the formation inward through cement 7 to the air or fuel conduits.

The transfer to heat outward to the formation causes thermal expansion of the oil and water trapped in the formation rock causing small fractures which permit the hydrocarbons to migrate to one or more recovery wells whereupon they are pumped to the surface. These migrating hydrocarbons would not necessarily travel upwards as shown in the Examiner's drawing on page 27 of the Office action, but would migrate in various directions through the numerous small fractures in the formation rock to the area of the recovery well(s). There is no disclosure in Mikus of using these migrating hydrocarbons from the formation (which would the effluent from the "process chamber" under the Examiner's interpretation of claims) to preheat the oxidant, nor would this happen inherently, since the flow of heat is outward from the heat injector through heat transferring cement 7 to the formation.

It is noted that Mikus does disclose that as the combustion products rise in the well bore above the formation being heated, they exchange heat with the combustion air (oxidant) and fuel gas traveling down the flow conduits (col. 6, lines12-15). However, the "combustion products" are effluent from the combustion portion of the heat injector, i.e., the oxidation chamber. They are not effluent from the process chamber. Hence, this disclosure in Mikus does not anticipate claims 17 or 24.

Since Applicant is relying on structural limitations (i.e., the present apparatus has a process chamber as an essential element, an oxidation chamber capable of providing heat at a rate of flux sufficient to complete the endothermic chemical reaction conducted in the process chamber, and in one embodiment the apparatus is configured so that the oxidant is preheated by heat exchange with effluent from the process chamber) to distinguish the present claims over Mikus, and not on statements made in the preamble, nor the manner in which the apparatus is

intended to be used, nor the contents thereof, the rationale of *In re Otto*, 312 F.2d 937, 938, 136 USPQ 458, 459 (CCPA 1963), etc., *Ex parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

In summary, claims 1 and 18 and the claims that depend there from, are clearly distinguishable from Mikus in that the naturally occurring, porous, underground formation in Mikus (which is further fractured by Mikus' heat injection process) cannot reasonably be said to be a process chamber, which is a critical element in each of the present claims.

Claims 5 and 20 are distinguishable from Mikus for the additional reason that the heat injector in Mikus does not have an oxidation chamber capable of providing heat to a process chamber at a rate of flux sufficient to complete the thermal cracking of hydrocarbons to produce olefins.

Claims 17 and 24 are patentable over Mikus for the additional reason that Mikus does not disclose preheating the oxidant by heat exchange with effluent from a process chamber. The transfer of heat in Mikus is from the heat injector in the wellbore to the formation. The effluent from the formation (the migrating hydrocarbons) is not used to preheat the oxidant.

Accordingly, the rejection of claims 1-5, 16-18, 20-21 and 24 as anticipated by Mikus is erroneous and should be reversed, which action is respectfully requested.

Claim Rejections – 35 U.S.C §103

The rejection of claims 1-7, 14-18 and 20-24 under 35 U.S.C. § 103(a) as being unpatentable over Ruhl (EP 0 450 872) is erroneous and should be reversed.

On page 13 of the November 2, 2004 Office Action the Examiner takes the position to the extent that Ruhl, in Fig. 4, does not show a plurality of nozzles distributed along substantially the entire length of the oxidation chamber, it would be obvious to an ordinary artesian at the time of the invention to extend the plurality of nozzles, because Ruhl teaches that said nozzles are "at spaced intervals along its length" (P5/L51-52). The quoted sentence on page 5 lines 51-52 in its entirety reads as follows:

> "As shown in Figure 4, combustion tube 30 has a feed gas tube 60 which has perforations or holes 64 at spaced intervals along its length and has one end 66 plugged or otherwise closed."

Thus, the phrase "at spaced intervals along its length" quoted in the Office action is part of the description of Fig. 4. In other words, Fig.4 shows what is meant by the phrase "perforations or holes 64 at spaced intervals along its length". According to Fig. 4 it means placing the perforations or holes in burner zone 68 in the middle of combustion tube 30. Thus,

the quoted phrase would not make it obvious to extend the plurality of nozzles along the entire length of the oxidation chamber (combustion tube 30).

On page 13 of the November 2, 2004 Office action the Examiner also argues it would be obvious to extend the nozzles along substantially the entire length of the oxidation chamber because "While one embodiment of spaced nozzles arrangement is presented in Fig.4, the reference does not exclude other embodiments including ones where the area having the nozzles is extended to cover substantially the entire length of the oxidation chamber." While Ruhl does not expressly exclude embodiments where the nozzles are extended to cover substantially the entire length of the oxidation chamber, this is not the issue. The issue is whether the extension of the nozzles over the entire length of the oxidation chamber would be obvious based on the teachings of the reference. Appellant contends that based on Ruhl's teachings as a whole, such extension of the nozzles would not be obvious. For example, on page 3, lines 54-55, Ruhl teaches an important feature of the disclosed apparatus is that it allows for the use of relatively low temperature seals (seals 32) to seal the ends of combustion tube 30. Further, on page 5, lines 55-56, Ruhl discloses that plug 66 at the upper end of combustion tube 30 need not resist very hot temperatures. Since Ruhl clearly desires lower temperatures at the ends of combustion tube 30 (where combustion tube 30 is sealed to the plates 16 and 18), it would not be obvious to extend the nozzles along the entire length of the oxidation chamber since such extension would increase the temperatures at the ends of the combustion tube thereby not allowing the use of low temperature seals. Thus, Ruhl in fact teaches away from the extension of the fuel nozzles to cover substantially the entire length of the oxidation chamber (i.e., combustion tube 30).

The subject matter of claims 17 and 24 is not obvious over Ruhl for the additional reason that here is no teaching or suggestion in Fig. 4 of Ruhl of using process effluent (the stream which exits the reactor via outlet 24) to preheat the oxidant (air), which enters the reactor through air inlet 40. While Ruhl discloses it may be desirable to preheat the air fed into the heat generating means, the method contemplated by Ruhl for preheating air is a conventional preheater. Ruhl teaches that "such devices are known in the art and are commercially available" (Page 5, line 45).

As discussed above, the argument made in paragraph 11 of the November 2, 2004 Office action is untenable because the inherent heat exchange pointed out by the Examiner takes place between the reaction products in the process chamber and the oxidant in oxidant manifold 42. The effluent from the process chamber in Ruhl is the gas which emerges from outlet 24. Ruhl does not disclose utilizing this effluent stream for preheating the oxidant. Whatever minimal inherent preheating of the oxidant occurs in Ruhl, takes place in the reactor

by heat exchange through steel plate 16 with reaction products present in the process chamber. There is no disclosure using effluent from the process chamber for preheating the oxidant. Therefore, claims 17 and 24 are believed to be patentable over Ruhl for this reason as well as the reason discussed above in connection with claims 1 and 18, i.e., it would not be obvious to extend the fuel nozzles 64 along the entire length of combustion tube 30 since Ruhl clearly desires lower temperatures at the ends of combustion tube 30.

The rejection of claims 6-7, 14-15 and 22-23 under 35 U.S.C. § 103(a) as being unpatentable over Mikus (USP 5,255,742) as applied to claims 1 and 18 above, is erroneous and should be reversed.

Regarding claims 6-7, 14-15 and 22-23, contrary to the statement on page 13 of the November 2, 2004 Office action, Mikus does not disclose all the claim limitations of claims 1 and 18. As discussed above, the naturally occurring, porous, underground formation which is further fractured by the heat injection process of Mikus, cannot reasonably be said to be a "process chamber" suitable for completing the type of endothermic chemical reactions recited in claims 6-7, 14-15 and 22-23.

The statement on page 13 of the November 2, 2004 Office action that "Additionally Mikus discloses that the heater is used for an endothermic process" apparently is based on the disclosure in col. 1, lines 36-42 of Mikus that: "When the formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ. The products of the pyrolysis will be of lower molecular weights and will therefore be more valuable than the original oil." (emphasis added).There is no disclosure in Mikus of any specific endothermic chemical reactions, or the extent to which the reactions are completed, or what products are produced, other than they are lower molecular weight than the hydrocarbon solids originally trapped in the formation. Considering the teachings of Mikus as a whole, it is clear that any such in-situ pyrolysis, if it occurs at all, is incidental to the primary purpose of the heat injection process of Mikus, which is to fracture the formation by thermal expansion of the oil and water trapped within the pores, to allow the hydrocarbons to migrate through the fractures in the formation to a point they can be recovered.

More importantly, the teaching that the heater in Mikus may produce some incidental in-situ pyrolysis when heating underground formations, would not render it obvious to use such a heater to complete the quite different endothermic chemical reactions such as steam methane reforming, the production of styrene by the dehydrogenation of ethyl benzene, etc., recited in claims 6-7, 14-15 and 22-23. While the 375 watts/foot heat flux taught by Mikus may be sufficient to fracture the formation to allow migration and recovery of entrapped hydrocarbons,

and may result in some in-situ pyrolysis of solid hydrocarbons to lower weight molecular products, this would not render it obvious to use the heater in Mikus to provide heat to an endothermic chemical reaction involving flowing process streams conducted in an above ground reactor. As stated in the affidavit by Dr. Thomas Mikus these types of endothermic chemical reactions involve an order of magnitude greater heat flux than the 375 watts/foot rate produced by the heater in the Mikus reference. (A copy of Dr. Mikus' affidavit is provided in Appendix B for the Board's convenience.)

One skilled in the chemical process arts would be aware of the significantly greater heat flux required to complete the type endothermic chemical reactions recited in claims 6-7, 14-15 and 22-23, than the 375 watts per foot produced by the heat injector in Mikus. For this reason, an ordinary artesian at the time the invention was made would not have "replaced the heaters in various endothermal process chambers with the process heater in Mikus", as stated on page 14 of the November 2, 2004 Office Action.

Moreover, such replacement would not "amount to nothing more than to use a known process heater for its intended use in a known environment to accomplish entirely expected result" as also stated on page 14 of the November 2, 2004 Office action. The "intended use" of the heater in Mikus is to provide heat to an underground, porous, rocky formation containing trapped hydrocarbons. Not to provide heat to flowing chemical process streams in an above ground reactor. The "environment" in Mikus is an underground formation comprising rocky materials which retain heat and are good insulators and therefore can be heated using a relatively low rate of heat flux. In contrast, the "environment" in which endothermic chemical reactions are conducted involve flowing process streams, which rapidly carry heat away from the heat source and thus require a much higher rate of heat flux. Because of this, such replacement would not accomplish an "entirely expected result". As stated by Dr. Mikus in his affidavit, the results obtained with the flameless, distributed combustion process heater of the present invention were in fact very surprising and quite unexpected.

For all the foregoing reasons, claims 6-7, 14-15 and 22-23 are believed to be patentable over Mikus. Accordingly, it is respectfully requested the Examiner's rejection of these claims be reversed.

The rejection of claims 1-7, 14-18 and 20-24 under 35 U.S.C. § 103(a) as being unpatentable over Ruhl (EP 0 450 872) in view of Mikus (USO 5,255,742) is erroneous and should be reversed.

As discussed above, Ruhl does not disclose a critical feature of the present apparatus recited in each of the present claims that the plurality of fuel nozzles in the fuel conduit be

distributed along substantially the entire length of the oxidation chamber. The apparatus in Fig. 1 of Ruhl does not even have a plurality of fuel nozzles and clearly shows a flame in flame zone 50. The apparatus shown in Fig. 4 of Ruhl has a plurality of nozzles (64). However, they are not "distributed along substantially the entire length of said oxidation chamber" (combustion tube 30). Instead, all of perforations or holes 64 in Fig. 4 of Ruhl are spaced in burner zone 68 which represents only a minor portion (appears to be roughly 20%) of the overall length of combustion tube (oxidation chamber) 30. There are no perforations in the upper portion or the lower portion of combustion tube 30. This uneven distribution of fuel nozzles in the oxidation chamber will result in an uneven temperature distribution in combustion tube 30, with the temperature in "burner zone" 68 of the combustion tube 30 being greater than the temperature in the upper or lower portions of combustion tube 30, which allows the use of low temperature seals to seal the combustion tube to plates 16 and 18.

In an attempt to overcome fact the heaters in Figs. 1 & 4 of Ruhl by design have an uneven temperature distribution (i.e., higher temperatures in the middle of the combustion tube and lower temperature at the ends to permit the use of low temperature seals), on page 16 of the November 2, 2004 Office action it is stated that: "Further Ruhl discloses an embodiment wherein the process heater is designed to operate with low temperature differentials (P6/L7-10)". The portion of Ruhl cited by the Examiner in its entirety reads as follows:

> "In general, for the apparatus of the present invention, the combustion tubes require a length to inside diameter of typically 500 to 700 in order to achieve the required heat transfer per unit flow volume for a natural gas plus steam reforming application. Even higher ratios are needed, if the reactor is to operate with low temperature differentials."

The quoted disclosure in Ruhl teaches that if it is desired to operate the reactor with low temperature differentials, higher ratios of length to inside diameter are required. There is nothing in this teaching that changes the fact that Ruhl desires lower temperatures at the ends of the combustion tubes to allow for the use of low temperature seals. While using tubes with higher tube length to inside diameter ratios results in lower temperature differentials across the reactor, the use of such higher tube length to inside diameter ratios would not create a uniform temperature profile along the length of combustion tube(s) 30, as long as the nozzles remain located in burner zone 68 in the middle of the combustion tube(s) 30.

In a further attempt to increase the relevancy of Ruhl, it is stated on page 16 of the November 2, 2004 Office action that: "To enable operation with low temperature differentials the reference discloses embodiments where the so called 'low temperature seals' are replaced by

'high temperature seals' (P6/L29-31) or where an alternative mode of operation is provided which allows said 'low temperature seals' to effectively operate at high temperatures (P6/L57-P7/L2)". These statements are not accurate for a number of reasons as discussed below.

The first cited portion of Ruhl reads: "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes." Ruhl goes on to state "The cold-end seal could be an O-ring or graphite foil type to allow tube thermal expansion." (Page 6, lines 31-32).

From these statements it can be seen that the replacement of the low temperature seals with high temperature seals has nothing to do with enabling "operation with low temperature differentials". The purpose of the replacement is to arrange for the cocurrent flow of combustion gases and process gases. From these statements taken together, it is clear that in the disclosed variation, only the seals on the exhaust end of the combustion tubes are replaced with high temperature seals. The seals on the opposite "cold-end" of the combustion tubes in the vicinity of the feed inlet and air and fuel inlets would continue to be low temperature seals. Thus, this variation in which the combustion gases and process gases are in cocurrent flow would not have a uniform or even temperature profile. The temperature in the burner zone and the exhaust end of the combustion tubes would be higher than the temperature in the "cold-end" of the combustion tubes.

The second cited portion of Ruhl reads "The upper operating temperature of the graphite foil seals is limited by oxidation by the air present on one side. If a controlled very slow leakage of process gas is permitted to occur through the seal, this could sweep this air away from the seal material and permit the seals to exhibit long life at higher temperatures. Such an arrangement may be termed a purged seal condition."

Ruhl does not define what is meant by "higher temperatures". All we know is that use of a "purged seal condition" permits the use of the relatively low temperature seals at somewhat higher temperatures than if the seals were exposed to an oxidizing atmosphere. Ruhl does not teach (nor would it be reasonable to expect) that use of a purge seal condition would allow the relatively low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor does Ruhl teach that if a "purged seal condition" is used, the fuel nozzles in Fig. 4 should be placed in a location other than burner zone 68, or that a different plug 66 should be used, other than a plug that need not resist very high temperatures. Thus, when the disclosures of Ruhl are taken as a whole, the teaching that the preferred relatively low temperature graphite foil seals can be operated under a purged seal condition at some undefined "higher temperature" would not render it obvious to distribute the fuel nozzles along substantially the entire length of the oxidation chamber.

Turning now to Mikus, Appellant strongly disagrees with the statement on page 17 of the November 2, 2004 Office action that Mikus teaches a process heater comprising *inter alia*:

> "- a process chamber (1) in a heat exchange relationship with the oxidation chamber (Fig. 2-3), whereby a controlled heat flux is provided to the process chamber at a sufficiently high rate to complete the endothermic process being conducted therein (C1/L13-44)".

As discussed above, item (1) in Figs. 2-3 of Mikus cannot reasonably be said to represent a "process chamber". Item 1 represents the "formation to be heated" (Mikus, col. 7, line 45). The "formation to be heated" is a naturally occurring, geological structure located hundreds or even thousands of feet underground, that basically consists of rocky materials which may contain oil and water trapped in the pores of the formation rock. Injection of heat into the formation causes thermal expansion of the water and oil trapped within the pores of the formation rock causing fractures. The hydrocarbons migrate through the small fractures created by the expansion and vaporization of oil and water. (See Mikus col.1, lines 24-36). Appellant maintains it is unreasonable to refer to this fractured, porous formation as a "process chamber" as this term is in the present specification and claims and would be understood by one skilled in the relevant art i.e., the chemical process art.

Appellant also strongly disagrees with latter portion of the quoted statement, that the oxidation chamber in Mikus provides a controllable heat flux to the process chamber "at a sufficiently high rate to complete the endothermic chemical process being conducted therein". As discussed above and supported by the affidavit of Dr. Thomas Mikus, the relatively low rate of heat flux (e.g., 375 watts per foot) produced by the heat injector of Mikus, would not be sufficiently high to complete the endothermal chemical process being conducted in the process chamber.

Examiner's Basis for Combining Ruhl with Mikus

Despite the fact that the heaters in Figs. 1 and 4 in Ruhl, by design, have an uneven or non-uniform temperature distribution in order to allow the use of low temperature seals, on page 18 of the November 2, 2004 Office action the Examiner takes the position that:

> "It would have been obvious to one of ordinary skill in the art at the time the invention was made to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of providing more even temperature distribution throughout the length of the burner and lowering the costs of said apparatus."

Applicant's Arguments as to Why Ruhl is Not Properly Combinable with Mikus

It basic patent law that the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ 2d 1430 (Fed. Cir. 1990). Although a prior art device "may be capable of being modified to run the way the apparatus is claimed, there must be a suggestion or motivation in the reference to do so." 916 F.2d at 682, 16 USPQ2d at 1432.

Appellant submits that in the present case, there is no suggestion or motivation in the Ruhl or Mikus references for modifying them in the manner the Examiner has done. The Examiner's position that it would be obvious "to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of providing more even temperature distribution throughout the length of the burner and lowering the costs of said burner" is based on the erroneous assumption that an "even" or "uniform" temperature distribution throughout the length of the burner, which is taught by Mikus to be beneficial in heating subterranean formations, is also beneficial in heater used by Ruhl to provide heat to his endothermic reaction apparatus. This assumption is not correct, and in fact contrary to the disclosure in Ruhl.

As previously discussed, the heater (combustion tube 30) in the apparatus in Fig. 1 of Ruhl does not have a "even" or "uniform" temperature distribution along the length of the combustion tube, nor is there any teaching that an "even" or "uniform" temperature distribution is desired. To the contrary, Ruhl prefers the use of low temperature seals 32 to hold the combustion tube in place. Therefore, the combustion tube in Fig. 1 of Ruhl intentionally has the highest temperatures in flame zone 50 (in the middle of combustion tube 30), with lower temperatures at the upper and lower portions of the combustion tube to allow the use of low temperature seals to join the combustion tube to the tube sheets (plates 16 and 18).

Likewise the heater in Fig. 4 of Ruhl does not have an "even" or "uniform" temperature distribution since all of the fuel nozzles in Fig. 4 are in the "burner zone" 68 in the middle portion of combustion tube 30. There are no fuel nozzles in the upper portion or lower portion of the combustion tube 30. Consequently, these portions will have lower temperatures than the temperature in the "burner zone" 68, thereby allowing the use of low temperature seals. Lower temperatures in the upper portion of combustion tube also allow the use of a plug 66 at the upper end of the fuel tube which "need not resist very hot temperatures and thus could be made of graphite or heat resistant organic cement" (page 5, lines 55-56).

Since the heaters in both Fig. 1 and Fig. 4 of Ruhl by design have a non-uniform temperature distribution along their length, and since there's no indication in Ruhl that an "even"

or "uniform" temperature distribution is desirable, it would not be obvious to one skilled in the art to replace the heater in the apparatus of Ruhl with the heater in Mikus for "the purpose of providing more even temperature distribution throughout the length of the burner", as contended by the Examiner. The teaching or suggestion to combine these references and a reasonable expectation for success must both be found in the prior art, and not based on applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 20USPQ2d 1438 (Fed. Cir. 1991). Applicant submits that in the present case the prior art does not suggest replacing the heater in either Fig. 1 or Fig. 4 of Ruhl with the heat injector in Mikus, nor does the prior art create a reasonable expectation that such substitution would be successful.

The fact that the heaters used in Figs. 1 and 4 of Ruhl have a non-uniform temperature distribution along their length, while the heater in Mikus is designed to produce an "even" or "uniform" temperature distribution, again illustrates the differences between the problems to which Ruhl and Mikus were directed, and why these references are not properly combinable. Ruhl wanted to design a compact reactor apparatus which can employ a large number and high density of burner tubes which could operate at high temperatures and pressures to achieve a high conversion of hydrocarbon with high efficiency. (Page 3, lines 50-53). Yet Ruhl also wanted an apparatus which allows for the use of relatively low temperature seals to connect the burner tubes to the tube sheets. (Page 3, lines 54-55). Therefore, Ruhl designed combustion tube 30 to have lower temperatures at the ends of the combustion tube in the general vicinity of the seals, with higher temperatures in the middle of the combustion tube (i.e., in "flame zone" 50 in the case of Fig.1, and in "burner zone" 68 in the case of Fig. 4).

Mikus, on the other hand, was concerned with recovery of hydrocarbons entrapped in pores in an underground formation and found that the provision of uniform heat to the formation at a relatively low heat flux was beneficial. Mikus was not concerned with designing compact reaction apparatuses, or conducting the type of endothermic chemical reactions of interest to Ruhl which require a high rate of heat flux, or joining combustion tubes to tube sheets with low temperature seals. Since the problems to which Ruhl and Mikus are directed, and the solutions they found, are quite different, it clearly would not be obvious to replace the heater in Ruhl with the heater of Mikus " for the purpose of providing more even temperature distribution throughout the length of the burner". Such substitution would not solve the problems to which Ruhl was directed, nor achieve the benefits Ruhl desired.

Appellant further submits there are at least three reasons why it would not be obvious to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of "lowering the costs of said apparatus".

One reason is that 375 watts/foot rate of heat flux produced by the heater in Mikus would not be adequate to complete the type of endothermic chemical reactions of interest to Ruhl which require an order of magnitude greater rate of heat flux (See affidavit by Dr. Thomas Mikus). Since replacement of the heater in reaction apparatus of Ruhl with the heater in Mikus which produces 375 watts/foot heat flux would most likely result in an inoperable process, such replacement would not "lower the costs of said apparatus". An inoperable process has no value.

A second reason is the fact that Ruhl desires a compact reactor which can employ a large number and high density of burner tubes (Page 3, lines 50-53). Ruhl teaches one design could use 10,000 tubes of relatively small inside diameter, e.g., 0.4 inches inside diameter x 20 feet in length. (Page 6, lines 23-24). The heater in Mikus, on the other hand, has a relatively large diameter, e.g., between 4 and 8 inches, and may be hundreds or even thousands of feet in length depending on the depth and thickness of the underground formation (Col. 5, lines 19-25). Because of the significant difference in dimensions of the heating tubes (diameter and length), it is clear that substantial modifications would be required in an attempt to replace the combustion tubes in the reactor apparatus of Ruhl with the heater used in the heat injection process of Mikus. Such modifications, if they could be made at all, would undoubtedly be very expensive, and would not necessarily result in a less expensive reactor.

A third reason why it would not be obvious to replace the heater in Fig.1 of Ruhl with the heater in Mikus "to reduce costs of the apparatus", is that the heater in Fig. 1 of Ruhl has higher temperatures in flame zone 50 in the middle of the combustion tube with lower temperatures in the upper and lower portions of the combustion tube to permit the use of low temperature seals. Since the heater in Mikus produces an even temperature distribution, i.e., the same temperature at the ends of the combustion zone as in the middle, it is not clear that such substitution would permit the use of the low temperature seals preferred by Ruhl. If such substitution required the use of high temperature seals to seal the combustion tubes to the tube sheets, such substitution could actually increase the cost of the apparatus, rather than reduce it.

Appellant submits that when the Ruhl and Mikus references are considered as a whole, rather that suggesting to one skilled in the art to replace the heater of Ruhl with the heat injector of Mikus, they provide at least two significant reasons for <u>not replacing</u> the heater of Ruhl with the heat injector of Mikus. (1) The heaters used to provide heat to the endothermic reaction apparatuses in Figs. 1 and 4 of Ruhl have a <u>non-uniform temperature distribution by design</u>, and there is no indication that an even temperature distribution is desired, and (2) endothermic chemical reactions, such as the reforming of light hydrocarbons, which are of interest to Ruhl, require far greater heat flux than the approximately 375 watts per foot produced by the heater

injectors used by Mikus to heat subterranean formations, as stated in the affidavit by Dr. Thomas Mikus.

In addition to the structural limitations recited in claims 1 and 18, Appellant is relying on the limitation in claims 17 and 24 that the oxidant be preheated by heat exchange with effluent from the process chamber to distinguish these claims from the cited art. Applicant considers the additional limitation recited in claims 17 and 24 to be a structural limitation, since it pertains to a particular configuration of the process heater of the invention in which the oxidant is preheated by heat exchange with gaseous effluent from the process chamber. Neither Ruhl nor Mikus teach or suggest such this embodiment of Appellant's process heater. Ruhl appears to contemplate use of a separate, external preheater to preheat the oxidant, and states such preheaters are known in the art and are commercially available (Ruhl, page 5, lines 44-45). Some minimal preheating may occur in Ruhl by heat exchange between the reaction products in the process chamber and the air in manifold 42. However, there is no disclosure of using the effluent from the process chamber (i.e., the stream exiting the reactor through outlet 24) to preheat the oxidant.

There is no suggestion in Mikus of using "effluent" from a process chamber (which according to the Examiner's interpretation would be the hydrocarbons released from the fractured, porous underground formation) to preheat the oxidant. As discussed above, in the heat injection process disclosed in Mikus, the heat flows from the heat injector outward through cement 7 into the formation. There is no flow of heat from the formation inward through the cement to the air conduit or fuel conduit which comprises the heat injector. Thus, Mikus does not teach or suggest preheating the oxidant with effluent from a process chamber.

Since Applicant is relying on structural limitations to distinguish the present claims over Ruhl and Mikus (e.g., that the plurality of fuel nozzles be distributed along substantially the entire length of the oxidation chamber and that the oxidant be preheated by heat exchange with effluent from the process chamber), and not on statements made in the preamble, nor the manner in which the apparatus is intended to be used, nor the contents thereof, the rationale of *In re Otto*, 312 F.2d 937, 938, 136 USPQ 458, 459 (CCPA 1963), etc., *Ex parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

For the foregoing reasons, claims 1-7, 14-18 and 20-24 are believed to be patentable over Ruhl in view of Mikus. Accordingly, it is respectfully requested that the Examiner's action in rejecting these claims under 35 U.S.C. § 103(a) be reversed.

Response to Examiner's Arguments Made in Paragraphs 9-17 of the November 2, 2004 Office Action

In this section Appellant will address the points raised in Paragraphs 9-17 of the November 2, 2004 Office Action, which were made by the Examiner in response the arguments presented in Appellant's response filed July 30, 2004. Certain of the points raised by the Examiner in Paragraphs 9-17 have already been addressed to some extent in previous sections of this Brief. Appellant apologizes for any redundancy , but wants to ensure that all of the points and issues raised by the Examiner in the Office action are adequately addressed, in order that the Board may reach an appropriate decision on merits, which Appellant believes will result in allowance of the claims on appeal.

Paragraph 9. Appellant agrees that claim terms should be given there broadest reasonable interpretation consistent with the specification. However, it is not reasonable, nor consistent with the specification, for the Examiner to interpret the term "oxidation chamber" as applied to Ruhl, to include only that part of combustion tube 30 surrounding the burner zone 68. Combustion tube 30 in the apparatus of Fig.4 of Ruhl runs the full length of the reactor. There are no walls or barriers dividing combustion tube 30 into separate sections or compartments. Oxidant and fuel are free to mix and combust anywhere in combustion tube 30. Hence, it is unreasonable for the Examiner to define the oxidation chamber in Ruhl as being only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation chamber in the reaction apparatus in Fig.4 of Ruhl. Since the fuel nozzles (perforations 64) in Ruhl are distributed over only a small portion (about 20%) of combustion tube 30 (i.e., in burner zone 68), Ruhl does not met the limitation in each of the present claims that the fuel nozzles be distributed along substantially the entire length of the oxidation chamber.

The Examiner points out that while Fig. 4 of Ruhl may not explicitly show nozzles along the entire length of feed tube 60, the disclosure of Ruhl is not limited to the embodiment shown in Fig. 4. The Examiner notes that Ruhl on page 5, lines 51-53 teaches that the nozzles are spaced at intervals along the length of feed tube 60. Further the reference is silent as to any requirements of a "non-burner zone"- area of the feed tube 60 which is free of nozzles. In view of this disclosure, the Examiner argues it would be obvious to one skilled in the art "to extend said plurality of nozzles to cover substantially the entire length of the oxidation chamber.

The quoted disclosure on page 5, lines 51-52, of Ruhl in its entirety reads as follows: "As shown in Figure 4, combustion tube 30 has a feed gas tube 60 which has perforations or holes 64 at spaced intervals along its length and has one end 66 plugged or otherwise closed." Thus, the phrase "at spaced intervals along its length" cited in the Office action is part of the

description of Fig. 4. In other words, Fig.4 shows what is meant by the phrase "perforations or holes 64 at spaced intervals along its length". According to Fig. 4 it means placing the perforations or holes in the middle of combustion tube 30, i.e., in burner zone 68. Thus, the quoted phrase would not make it obvious to extend the plurality of nozzles along the entire length of the oxidation chamber (combustion tube 30).

While Ruhl may be "silent as to any requirements of a 'non-burner zone' – area of the feed tube 60 which is free of nozzles", this is not the issue. The issue is not whether Ruhl expressly excludes the extension of the plurality of nozzles to cover substantially the entire length of the oxidation chamber. The issue is whether such extension would be obvious. Appellant contends that such extension would not be obvious in view of Ruhl's teachings on page 3, lines 54-55 and page 5, lines 55-56, that the apparatus of the invention allows for the use relatively low temperature seals to seal the ends of combustion tube 30 to plates 16 and18, and a that plug 66 (located at the upper end of combustion tube 30) need not resist very hot temperatures. Since Ruhl clearly desires lower temperatures at the ends of combustion tube 30 to allow the use of relatively low temperature seals and a plug that need not resist very hot temperatures, it would not be obvious to extend the nozzles 64 along the entire length of combustion tube 30.

The Examiner finds Appellant's arguments with respect to low temperature seals limiting the area of the oxidation chamber in Ruhl in which flameless combustion would occur to be unpersuasive "because Ruhl teaches an alternative to said low temperature seals. On page 6, lines 29-32 Ruhl teaches 'hot seals' which can comprise, for example, fused glass or ceramic cement."

The quoted disclosure on page 6, lines 29-32, of Ruhl in its entirety reads as follows:

> "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes. Such a seal might be made of fused glass or a ceramic cement, for example. The cold end seal could be an O-ring or graphite foil type to allow tube thermal expansion."

The quoted disclosure would not make it obvious to extend the plurality of nozzles along the entire length of the oxidation chamber (combustion tube 30), since only the exhaust ends of the combustion tube would have a hot seal, and thus could withstand higher temperatures. The other end of the combustion tubes would continue to have a "cold-end seal" such as an O-ring or graphite foil seal, which could not withstand higher temperatures. Therefore, in this alternative embodiment, the combustion tube(s) would still have a non-uniform temperature profile. Since Ruhl teaches that an important "feature of present design is that it allows for the

use of lower temperature seals where the combustion tubes are joined to the tube sheet" (page 4, lines 48-49), there is no incentive to replace the low temperature seals on both ends of the combustion tube with "hot seals".

The Examiner also finds Appellant's arguments with respect to low temperature seals limiting the area of the oxidation chamber in Ruhl in which flameless combustion would occur to be unpersuasive because Ruhl teaches "that while the upper operating temperature of graphite seals is limited by oxidation, the apparatus can be operated with a controlled very slow leakage of process gas through the seal to sweep the air away from the seal material and permit seals to exhibit long life at higher temperatures (see Ruhl, P6/L57-P7/L2)".

The cited portion of Ruhl in its entirety reads:

> "The upper operating temperature of the graphite foil seals is limited by oxidation by the air present on one side. If a controlled very slow leakage of process gas is permitted to occur through the seal, this could sweep this air away from the seal material and permit the seals to exhibit long life at higher temperatures. Such an arrangement may be termed a purged seal condition."

Ruhl does not define what is meant by "higher temperatures". All we know is that use of a "purged seal condition" permits the use of the relatively low temperature seals at somewhat higher temperatures than if the seals were exposed to an oxidizing atmosphere. Ruhl does not teach (nor would it be reasonable to expect) that use of a purge seal condition would allow the relatively low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor does Ruhl teach that if a "purged seal condition" is used, the fuel nozzles in Fig. 4 should be placed in a location other than burner zone 68, or that a plug 66, other than a plug that need not resist very high temperatures should be used. Thus, when the disclosures of Ruhl are taken as a whole, the teaching that the preferred relatively low temperature graphite foil seals can be operated under a purged seal condition at some undefined "higher temperature" would not render it obvious to extend the fuel nozzles along substantially the entire length of the oxidation chamber.

Paragraph 10. Appellant is relying on structural limitations to distinguish the present claims over the references and not on the fact the apparatuses in the prior art are not able to achieve the range of temperature profiles that are achieved by Appellant's apparatus. It is because of structural limitations, such as the placement of a plurality of fuel nozzles along substantially the entire length of the oxidation chamber, that Appellant's apparatus is able to tailor the temperature profile in the process chamber to whatever profile is needed to complete the endothermic chemical reaction being conducted therein. Since Appellant is relying on

structural limitations rather than specific temperature profiles to distinguish over the references, there is no need to recite particular temperature profiles in the claims.

Paragraph 11. In response to Appellant's argument that Ruhl does not disclose preheating the oxidant by heat exchange with effluent from the process chamber, the Examiner on page 25 of the November 2, 2004 Office action, reproduces a portion of Fig. 4 of Ruhl, which it is said "clearly shows that the oxidant in Oxidant Inlet Manifold 42 is preheated by heat exchange (heat being inherently transferred by the Steel Plate 16 with reaction products produced in the process chamber and traveling towards the Outlet 24".

Appellant agrees it is possible that there may be some inherent heat transfer from the reaction products in the process chamber to the oxidant in manifold 42. However, claims 17 and 24 call for preheating the oxidant with effluent from the process chamber. "Effluent" is the gaseous stream that exits packed bed 20 (the "process chamber" in Ruhl) via outlet 24. Ruhl does not disclose using this effluent stream from the process chamber to preheat the oxidant. Instead Ruhl teaches using a known, commercially available preheater device to preheat the oxidant (Ruhl, page 5, lines 44-45). Whatever minimal additional preheating occurs, takes place as the result of heat exchange between the reaction products in the process chamber and the oxidant in manifold 42. Ruhl does not disclose preheating the oxidant using effluent from the process chamber (i.e., the stream exiting the reactor via outlet 24).

Paragraph 12. Appellant acknowledges that Mikus does disclose that the injection of heat into a formation may in some cases result in in-situ pyrolysis of hydrocarbons which is an endothermic chemical reaction. More specifically, Mikus discloses in col. 1, lines 36-42, when a formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ, thereby producing products with lower molecular weights which will therefore be more valuable than the original oil. However, there is no disclosure in Mikus of any specific endothermic chemical reactions which result from the in-situ pyrolysis, or the extent to which the reactions are completed, or what products are produced, other than they are lower molecular weight than the hydrocarbon solids originally trapped in the formation.

In any case, Appellant is not relying on the fact the present process heater is designed to provide heat to an endothermic chemical process to distinguish the present claims over Mikus. As discussed above, Appellant believes the present claims are distinguishable over Mikus in that the apparatus used in the heat injection method of Mikus does not have a process chamber, which is an essential component of the present apparatus, and also that the 375 watts per foot rate of heat flux produced by the heat injector in Mikus is not sufficient to complete the

endothermic chemical process being conducted in the process chamber, which is also a limitation in the claims.

As discussed above, the porous, underground formation which is heated by Mikus' heat injection process is an occurrence in nature. It was not created by Mikus and is not part of Mikus' heat injector apparatus. Therefore, it cannot reasonably be said to anticipate the present process heater apparatus which has a process chamber as an essential and integral part of the claimed process heater apparatus.

The Examiner refused to accept these important distinctions stating in the middle of page 26 of the November 2, 2004 Office action that "it is noted that the features upon which applicant relies (i.e., process chamber being created by Mikus or being an integral part of the process heater) are not recited in the rejected claim(s)."

Appellant submits it would be abundantly clear to one skilled in the art reading the present specification and drawings, that the "process chamber" element in Appellant's flameless distributed combustion process heater apparatus was created by Appellant and is not an occurrence in nature. Appellant submits it is unnecessary (and borders on ridiculous), to require Appellant to specify in the claims that the "process chamber" in the present apparatus was created by Appellant and is not an occurrence in nature.

Regarding the process chamber "being an integral part of the process heater", this is clearly evident from the claims, although the specific words "integral part" are not used in the claims. For example, it is recited in claim 1 that the process chamber (one of the principal elements of Appellant's process heater apparatus) is in heat exchange relationship with the oxidation chamber whereby a controllable heat flux is provided to process chamber at a sufficiently high rate to complete the endothermic process being conducted therein. From this recitation it is clear the "process chamber" in Appellant's process heater apparatus is an integral part of the claimed apparatus.

Paragraph 13. While Mikus teaches that the injection of heat into a formation may in some cases result in in-situ pyrolysis of hydrocarbons which is an endothermic chemical reaction, Mikus does not teach using a heat flux sufficient to complete the specific types of endothermic chemical process recited in claims 5-7, 14-15, 20 and 22-23 and therefore does not anticipate those claims for this reason as well as the reasons discussed elsewhere. While a specific rate of heat flux is not recited in claims 5-7, 14-15, 20 and 22-23, these claims do require that a controllable heat flux be provided to the process chamber at a rate necessary or sufficiently high to complete the endothermic chemical process conducted therein. One skilled in the chemical arts would know that the 375 watts/foot rate of heat flux produced by the heat injector in Mikus to heat underground formations, would not be sufficient to complete the

specific types of endothermic chemical reactions recited in claims 5-7, 14-15, 20 and 22-23. Therefore, these claims are believed to be distinguishable over Mikus because of the aforementioned limitation, even though they do not recite specific rates of heat flux.

Paragraph 14. In response to Appellant's argument that Mikus does not disclose preheating the oxidant by heat exchange with effluent from the process chamber, the Examiner on page 27 of the November 2, 2004 Office action, reproduces a portion of Fig. 2 of Mikus which it is said "clearly shows that the oxidant in Oxidant Conduit is preheated by heat exchange (heat is being inherently transferred by Heat Conductor 7 and Steel Oxidant Conduit) with reaction products produced in at least one process chamber traveling upwards".

Contrary to this statement, the oxidant in Mikus (combustion air) is not preheated by heat exchange with "reaction products produced in at least one process chamber traveling upwards". The heat injector shown in Fig. 2 of Mikus produces heat when preheated air traveling down combustion air conduit 10 is mixed with fuel gas passing through orifices 13 in fuel gas conduit 12 at a temperature above the autoignition temperature of the mixture. The heat generated by the resulting combustion is transferred outward to the formation through cement 7 which is said to be suitable for withstanding elevated temperatures and transferring heat (col. 4, lines 53-56). There is no transfer of heat from the formation inward through cement 7 to the air or fuel conduits.

The transfer to heat outward to the formation causes thermal expansion of the oil and water trapped in the formation rock causing small fractures which permit the hydrocarbons to migrate to one or more recovery wells whereupon they are pumped to the surface. These migrating hydrocarbons would not necessarily travel upwards as shown in the drawing on page 27 of the Office action, but would migrate in various directions through the numerous small fractures in the formation rock to the area of the recovery well(s). There is no disclosure in Mikus of using these migrating hydrocarbons (which would be the "effluent" from the fractured porous "process chambers") to preheat the oxidant, nor would this happen inherently, since the heat flow is outward from the heat injector through heat transferring cement 7 to the formation.

Paragraph 15. Appellant believes it is error for the Examiner to disregard the Affidavit of Dr. Thomas Mikus, the inventor on the Mikus reference and a co-inventor on the present application. As an inventor Dr. Mikus is considered one of extraordinary skill in the art. Yet the Examiner ignores the Dr. Mikus' testimony that because of the order of magnitude greater difference in heat flux requirements between endothermic chemical reactions, such as the thermal cracking of hydrocarbons to produce ethylene, and the heat flux required to heat underground formations (i.e., 3,500 to 7,000 watts/foot compared to 375 watts/foot), the applicability of flameless distributed combustion was unforeseen and not predictable. Instead,

the Examiner takes the position that one of ordinary skill in the art could manipulate the multitude of variables that affect the heat flux of a burner to compensate for the order of magnitude difference in heat flux requirements. If only some minor increase in the rate of heat flux was required in order to complete the type of endothermic chemical reactions of interest to Ruhl, Appellant might agree that manipulation of the multitude of available variables is within the capability of one of ordinary skill in the art. However, in view of the order of magnitude difference in heat flux required, Appellant submits that adaptation of flameless, distributed combustion to complete the very different type of endothermic chemical reactions to which the present apparatus is directed, requires more than ordinary skill in the art. It represents invention.

Appellant has previously noted, the fact that there may be "a multitude of variables" which could be modified or manipulated by one skilled in order to meet the claimed invention, is not sufficient by itself to establish *prima facie* obviousness without some objective reason to combine the teachings of the references. *Ex parte Levengood*, 28 USPQ 1300 (Bd. Pat. App. & Inter. 1993). On page 28 of the November 2, 2004 Office action the Examiner cites several teachings in the references, which the Examiner contends would make it obvious to replace the heater in Ruhl with the heater in Mikus. They do not for the following reasons.

For example, Ruhl's teaching on page 5, line 38-39, that "as many as many thousands of combustion tubes could be incorporated in an appropriate size reformer apparatus", refers to the relatively small diameter (e.g., 0.4 inch) ceramic combustion tubes which have higher temperatures in the flame zone in the middle portion of the combustion tube and lower temperatures at the ends to allow the use of relatively low temperature seals. (See page 5, lines 39-40, page 6, lines 19-23, and Figs. 1, 2 and 3 of Ruhl. The combustion tube in Fig. 4 of Ruhl also has an uneven temperature distribution.) Thus, the fact Ruhl teaches many relatively small diameter combustion tubes having an uneven temperature distribution can be used in a reformer apparatus, does not provide a motivation to replace these combustion tubes with the relatively large diameter (e.g., 4-8 inch) combustion tubes disclosed in Mikus, which produce an even temperature distribution and a low rate of heat flux. (See Mikus col. 5, lines 23-25 and lines 46-55 and col. 10, lines 8-12).

Likewise, the teaching on page 7, lines 4-7 of Ruhl, that "The maximum temperature of the combustion gases within the combustion tubes may be varied by adjusting the fuel composition and the fuel and air flow rates" refers to varying the maximum temperature of the combustion tubes in Ruhl which have an uneven temperature distribution. This teaching does not tell one skilled in the art how to produce a order of magnitude (i.e., a ten fold increase) in the rate of heat flux in the heater in Mikus, nor does not provide any motivation to replace the heater

in Ruhl which has an uneven temperature distribution with the heater in Mikus which has an even temperature distribution.

Finally, the teaching cited by the Examiner in col. 5, lines 15-25, of Mikus that "The heat that can be transferred into the formation increases significantly with increasing casing diameter" and that "A casing of between about 4 and about 8 inches in internal diameter will typically provide the optimum trade-off between initial cost and heat transfer", may suggest a means to optimize the heat transfer to an underground formation, but does not provide motivation to replace the heater in Ruhl, which preferably comprises of many thousands of small-diameter (e.g. 0.4"ID) ceramic tubes, with the much larger diameter (e.g. 4-8" ID) tubes employed by Mikus.

Ruhl clearly prefers the "use of small-diameter ceramic combustion tubes" to facilitate "a denser packing of burner tubes than has been previously available in prior art apparatus" (Ruhl, page 5, lines 39-40). "The preferred combustion tube inside diameter is usually equal to the tube separation distance (expressed as inside tube to inside tube surface). Thus, if the separation distance were 0.4 inches, the preferred tube ID would be 0.4 inches for a centerline spacing of 0.8 inches" (Ruhl, page 6, lines 19-21).

In view of Ruhl's desire for a compact apparatus which is achieved by employing many densely packed, relatively small diameter (e.g., 0.4 inch) burner tubes, it is submitted one skilled in the art would not be motivated by Mikus teaching of heat injectors with an optimum diameter of 4 to 8 inches for heating underground formations, to replace the densely packed, small diameter, burner tubes of Ruhl with the relatively large diameter burner tube preferred by Mikus. Such replacement would not result in a compact reactor, would not provide the same heat flux as many densely packed small diameter tubes, and in any case would not provide the uneven temperature distribution needed to allow for the use of low temperature seals and/or plugs.

In fact, Mikus' teaching that the heat transferred to the formation can be increased by increasing casing diameter is a reason for not replacing the heater in Ruhl with the heat injector in Mikus, since Ruhl achieves a high heat flux by using many tubes of a small diameter (by reducing the diameter of the tubes) so that they can be densely packed.

On page 29 of the November 2, 2004 Office action the Examiner "notes that a reasonable expectation for this proposed use of the flameless heater of Mikus in the apparatus of Ruhl is supported by the fact that Ruhl, in Fig. 4, discloses an embodiment wherein burner located in an oxidation zone comprises at least one fuel conduit comprising a plurality of fuel nozzles and does not have a flame." While Fig. 4 of Ruhl does disclose an embodiment having an oxidation zone comprising a fuel conduit with a plurality of nozzles and does not show a flame, as previously discussed, the plurality of nozzles in Fig. 4 of Ruhl are located in burner

zone 68 in the middle of combustion tube 30. There are no nozzles at either end of the combustion tube where the combustion tube is sealed to plates 16 and 18 with low temperature seals 32. Because of this uneven temperature distribution in the heater in Fig. 4 of Ruhl, and because of the lower rate of heat flux taught by Mikus, it is not reasonable to expect the flameless heater in Mikus would work as a replacement for the heater in Fig. 1 of Ruhl.

If one skilled in the art wanted to replace the heater in Fig. 1 of Ruhl with a flameless heater, they would have the greatest expectation of success if they choose the flameless heater in Fig. 4 of Ruhl, which has the same uneven temperature profile and uses the same low temperature seals as the heater in Fig. 1 of Ruhl. One skilled in the art would not choose the flameless heater in Mikus for such replacement.

Paragraph 16. Appellant's position is that it would not be obvious to replace the heater either in Fig.1 or Fig. 4 of Ruhl with the heater in Mikus because (1) the heater in Ruhl by design produces uneven temperature profile since the fuel nozzle(s) are located in the middle of the combustion tube 30 (in burner zone 68 or flame zone 50) while the ends of the combustion tube 30 is sealed with relatively low temperature seals and (2) the type of endothermic chemical reactions of interest to Ruhl and Applicant require an order of magnitude greater heat flux than that produced by the heater in Mikus. Ruhl repeatedly mentions the use of low temperature seals as an important feature of his compact reactor apparatus design (page 3, lines 54-55 and page 4, lines 48-49). It is for this reason, based on the teachings of the reference itself, that Appellant contends it would not be obvious to replace the low temperature seals in Ruhl with hot seals on both ends of the combustion tube(s), in order to be able to extend the fuel nozzles over substantially the entire length of the oxidation chamber (combustion tube 30).

With regard to the teaching on page 6 of Ruhl, lines 29-32, Appellant's description of this teaching is not overly narrow but based on a direct quote of the cited portion of Ruhl. Ruhl on page 6, lines 29-32 states that:

> "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes. Such a seal might be made of fused glass or a ceramic cement, for example. The cold-end seal could be an O-ring or graphite foil type to allow tube thermal expansion."

From this disclosure it is clear that the reason for using a hot seal on the exhaust end of the ceramic tubes was because such seals were <u>required</u> in the variation where the combustion gases flowed concurrently with and process gases. On the other end of the ceramic tubes where hot seals were not required, Ruhl used the preferred low temperature seals.

Considering the teachings of Ruhl as a whole, rather than suggesting the type of seal used is not critical and that various known seals can be used successfully employed in the reactor, Ruhl suggests that the use of relatively low temperature seals is an important feature of the invention, and that such low temperature seals should be used except in those cases where hot seals are required. The only instance in which a "hot seal" was required in Ruhl was in one variation, and then only in the exhaust end of the combustion tubes. Otherwise, Ruhl used the preferred low temperature seals.

Regarding the "purged seal condition", the cited portion of Ruhl (P6/L57-P7/2) only discloses that use of this condition permits the seals to exhibit long life at "higher temperatures". Ruhl does not define what is meant by "higher temperatures". All we know is that use of a "purged seal condition" permits the use of the relatively low temperature seals at somewhat higher temperatures than if the seals were exposed to an oxidizing atmosphere. Ruhl does not teach (nor would it be reasonable to expect) that use of a purge seal condition would allow the relatively low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor does Ruhl teach that if a "purged seal condition" is used, the fuel nozzles in Fig. 4 should be placed in a location other than burner zone 68, or that a plug 66, other than a plug that need not resist very high temperatures should be used. Thus, when the disclosures of Ruhl are taken as a whole, the teaching that the preferred relatively low temperature graphite foil seals can be operated under a purged seal condition at some undefined "higher temperature" would not render it obvious to extend the fuel nozzles along substantially the entire length of the oxidation chamber.

Paragraph 17. In response to Appellant's argument that Ruhl desires an uneven temperature distribution (i.e., higher temperatures in the middle of the combustion tube and lower temperature at the ends to permit the use of low temperature seals), the Examiner points to the disclosure on Page 6, lines 7-10 of Ruhl, which discloses a method of operating the reactor with low temperature differentials. The Examiner contends that in view of this teaching and the disclosure in Mikus of a flameless burner having low temperature differentials, it would have been obvious to substitute the burner in Ruhl with the burner in Mikus. A closer reading of the references reveals that this argument is untenable.

The quoted portion of Ruhl in its entirety reads as follows:

> "In general, for the apparatus of the present invention, the combustion tubes require a length to inside diameter of typically 500 to 700 in order to achieve the required heat transfer per unit flow volume for a natural gas plus steam reforming application. Even higher ratios are needed, if the reactor is to operate with low temperature differentials."

From the foregoing, it can be seen that the way Ruhl teaches to redesign the reactor to achieve low temperature differentials is by increasing the length to inside diameter ratio of the combustion tubes, i.e., by using combustion tubes of greater length or smaller diameter. Ruhl does not teach or suggest achieving lower temperature differentials by changing the location of the fuel nozzles which would still be in the middle of the combustion tubes (in flame zone 50 or burner zone 68). Nor does Ruhl suggest achieving the lower temperature differentials by using seals other than the preferred low temperature seals. Thus, the redesigned low temperature differential reactor in Ruhl would have longer combustion tubes or tubes with smaller inside diameter. However, the combustion tubes would still have a non-uniform temperature profile.

The heater in Mikus, on the other hand, is designed to "accomplish a nearly even temperature distribution in the casing. A nearly even temperature profile within the casing results in more uniform heat distribution within the formation to be heated." Col. 5, lines 47-51. Thus, the lower temperature differential in Mikus refers to the even temperature profile within the well casing which produces a more uniform heat distribution to the formation. Since the heater in Mikus produces an even temperature profile, it would not be obvious to substitute it for the low temperature differential heater in Ruhl, which still would have a non-uniform temperature profile as discussed above.

The position stated on page 31 of the November 2, 2004 Office Action "that once a heater has been used for an endothermic process and proven to be an improvement over heaters using flames, it would have been obvious to one skilled in the art at the time of the invention to use said heater in place of heaters using flames in any other endothermic process" is believed to be untenable for several reasons.

1. One skilled in the art would know that the 375 watts per foot rate of heat flux produced by the heat injector in Mikus, while sufficient to cause some in-situ pyrolysis of hydrocarbons in an underground formation, would not be sufficient to complete endothermic chemical reactions, such as the production of ethylene by thermal cracking of hydrocarbons, steam methane reforming, etc., conducted in an above-ground reactor, since the latter involve flowing process streams which rapidly carry heat away from the reactor. Therefore, it would not be obvious to one skilled in the art to use the heater of Mikus in place of a flame-type heater in "any other endothermic process", particularly when such endothermic process requires an order of magnitude greater heat flux than the 375 watts/foot rate of heat flux produced by the heat injector in Mikus.

2. One skilled in the art reading Mikus would recognize the heater in Mikus produces a uniform or even temperature distribution along the portion of the heater that is in the formation.

Therefore, one skilled in the art would not attempt to replace a flame-type heater requiring an uneven temperature distribution (i.e., lower temperature at the ends of the combustion tube to permit the use of low temperature seals) with the heater in Mikus, since the Mikus heater produces an even temperature distribution.

Appellant disagrees with the statement on page 31 of the November 2, 2004 Office action that the motivation to replace the heater in Ruhl with the heater in Mikus is found in the references themselves. The teachings of the references must be considered in their entirety. While certain teachings in Mikus, for example that a elimination of a flame eliminates hot spots within the burner and surrounding structures, might provide some motivation to replace the heater in Ruhl with the heater in Mikus, other teachings such as Ruhl's requirement for an uneven temperature distribution to permit the use of low temperature seals, and the fact that the endothermic chemical reactions of interest to Ruhl require an order of magnitude greater heat flux than produced by the heater in Mikus, far outweigh any potential benefits of hot spot elimination in the burner or in the catalyst bed to prolong catalyst life. One skilled in the art is not going to replace the heater in Ruhl with the heater in Mikus to eliminate hot spots or to allow construction with less expensive materials, if the replacement heater does not produce a sufficient rate of heat flux to complete the chemical reactions of interest to Ruhl, or if such replacement is going to necessitate a substantial redesign of the reactor and not allow the use of low temperature seals. Viewed in their entirety, the references do not provide motivation for the replacement of the Ruhl heater with the Mikus heater. The reasons for not making such replacement far outweigh any reasons for making such replacement.

Conclusion

For all the foregoing reasons, and in view of the affidavit submitted by Dr. Mikus, it is submitted that all of the claims under appeal (claims 1-7, 14-18 and 20-24) are patentable over the cited references. Accordingly, it is respectfully requested that the action of the Examiner in finally rejecting these claims be reversed, and the application be passed to issue.

Respectfully submitted,

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APPENDIX A

Claims Under Appeal

U.S. Application No. 09/168,770

1. A process heater for endothermic chemical reactions comprising:

an oxidation chamber, the oxidation chamber having an inlet for an oxidant, an outlet for combustion products, and a flow path between the inlet and the outlet;

a fuel conduit for transporting a fuel to the oxidation chamber, the fuel conduit containing a plurality of fuel nozzles along substantially the entire length of the oxidation chamber, each nozzle providing fluid communication from within the fuel conduit to the oxidation chamber, the fuel nozzles being spaced so that the fuel is added to the oxidation chamber at a rate that no flame results when the fuel is mixed with the oxidant flowing through the flow path in the oxidation chamber thereby producing flameless, distributed combustion throughout said oxidation chamber;

a preheater in fluid communication with the oxidation chamber inlet, the preheater capable of preheating said oxidant to a temperature at which when said oxidant and the fuel are mixed in said oxidation chamber, the temperature of said mixture of oxidant and fuel exceeds the autoignition temperature of said mixture; and

a process chamber in a heat exchange relationship with the oxidation chamber whereby a controllable heat flux is provided to the process chamber at a sufficiently high rate to complete the endothermic chemical process being conducted therein, and the heat transferred from the oxidation chamber to the process chamber does not cause the temperature of the mixture of the oxidant and the fuel within the oxidation chamber to decrease below the autoignition temperature of said mixture of the oxidant and the fuel in the oxidation chamber.

2. The process heater of claim 1 further comprising a coke inhibitor injection system, the coke inhibitor injection system being in fluid communication with the fuel conduit wherein an amount of coke inhibitor is supplied effective to inhibit coke formation at fuel conduit operating temperatures.

3. The process heater of claim 1 wherein the fuel conduit is a tubular conduit essentially centrally located within the oxidation chamber.

4. The process heater of claim 3 wherein the oxidation chamber is essentially centrally located within the process chamber.

5. The process heater of claim 1 wherein the process chamber is a pyrolysis reaction chamber for the thermal cracking of hydrocarbons in the production of olefins.

6. The process heater of claim 1 wherein the process chamber contains a catalyst and is used for steam methane reforming.

7. The process heater of claim1 wherein the process chamber contains catalyst and is used for the production of styrene by the dehydrogenation of ethyl benzene.

14. The process heater of claim1 wherein the process chamber is used for the vacuum flash distillation of a feed.

15. The process heater of claim 1 wherein the process chamber is a hydrocarbon distillation column reboiler. .

16. The process heater of claim 1 wherein the endothermic chemical reaction is conducted in a single stage, and heat is provided to the process chamber by the oxidation chamber at a controlled temperature profile.

17. The process heater of claim 1 wherein the oxidant is preheated by heat exchange with effluent from the process chamber.

18. A flameless distributed combustion process heater for endothermic chemical reactions comprising:

an oxidation chamber, said oxidation chamber having an inlet for oxidant and an outlet for combustion products, and a flow path between said inlet and outlet;

a fuel conduit for transporting fuel into said oxidation chamber, said fuel conduit containing a plurality of fuel nozzles distributed along substantially the entire length of said oxidation chamber, said fuel nozzles being spaced so that the flow of said fuel through said fuel nozzles results in no flame when the fuel passes through the nozzles and is mixed with said oxidant flowing through said flow path in said oxidation chamber thereby producing flameless, distributed combustion throughout said oxidation chamber;

a preheater in fluid communication with said oxidation chamber, for preheating said oxidant to above a temperature at which when said oxidant and said fuel are mixed in said oxidation chamber, the temperature of said mixture of said oxidant and said fuel exceeds the autoignition temperature of said mixture; and

a process chamber in heat exchange relationship with said oxidation chamber, said plurality of nozzles distributed along substantially the entire length of said oxidation chamber being sized to provide the desired temperature distribution within said process chamber and the heat flux necessary to complete the endothermic chemical process being conducted therein.

20. The flameless distributed combustion process heater of claim 18 wherein the process chamber is a pyrolysis reaction chamber for the thermal cracking of hydrocarbons in the production of olefins.

21. The flameless distributed combustion process heater of claim 18 wherein said endothermic chemical reaction is conducted in a single reaction stage at a controlled temperature profile.

22. The flameless distributed combustion process heater of claim 18 wherein said process chamber contains catalyst and the process conducted in said process chamber is the production of styrene by the dehydrogenation of ethyl benzene.

23. The flameless distributed combustion process heater of claim 18 wherein said process chamber contains catalyst and the process conducted in said process chamber is steam hydrocarbon reforming to convert a hydrocarbon and steam to hydrogen, carbon monoxide and carbon dioxide.

24. The flameless distributed combustion process heater of claim 18 wherein said oxidant is preheated by heat exchange with effluent from said process chamber.

APPENDIX B

TH1042 (US)

AFFIDAVIT UNDER C.F.R. 1.132

I, THOMAS MIKUS, being duly sworn, depose and state as follows:

I am an employee of Shell Global Solutions, an affiliate of Shell Oil Company, a corporation organized and existing under the laws of the state of Delaware, having a place of business at One Shell Plaza, 910 Louisiana, Houston, TX 77252.

I have a BS degree and an MS degree in Mechanical Engineering from Massachusetts Institute of Technology. I also hold a PhD in Mechanical Engineering from Massachusetts Institute of Technology, with a thesis in combustion.

I have had twenty-one years experience in corporate research laboratories with Shell Oil Company and/or its affiliates, including six years in the combustion department, and five more years leading the combustion team. In addition I had five years experience in Exxon Research and Engineering's corporate research laboratories.

I am the sole inventor of the invention described and claimed in U.S. 5,255,742, and a co-inventor of the invention described and claimed in the above-identified U.S. Patent Application Ser. No. 09/168,770, filed October 8, 1998.

I invented the flameless combustion heat injector disclosed in U.S. Patent No. 5,255,742 (the Mikus reference) to provide heat to a well drilled through rocky materials. The heat injector was developed to replace electric line source heaters. Because rocky materials are very poor conductors of heat, I viewed the heat injector in my earlier patent

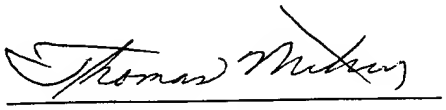
as a uniform, low flux, linear heat source, that typically provided only about 375 Watts per foot of length along the well.

In contrast, endothermic chemical processes of the type heated by the flameless distributed combustion (FDC) process heater disclosed in U.S. Serial No. 09/168,770, require significantly greater amounts of heat, since the flowing process streams normally carry the heat away from the heat source much faster than the rocky materials in a subterranean formation. Process streams typically absorb an order of magnitude higher heat flux than that produced by a heater of the same diameter as the well in my earlier patent. For example, to provide heat at a constant temperature to a process for the production of ethylene by the thermal cracking of hydrocarbons could require a profile of heat flux varying with distance from 3,500 to 7000 Watts per foot, as compared to the 375 Watts per foot provided by the heat injectors of my earlier invention.

Because of the significantly higher heat flux requirements of chemical process streams, the applicability of the flameless distributed combustion heat injectors to chemical process applications was unforeseen and not predictable. It was more than a decade after my original invention, that I and my co-inventors built a new rig to test a flameless distributed combustion heater design for a chemical process. Until these tests were conducted we had no way of knowing whether the FDC concept would work in a chemical process application. That fact that the new FDC process heater worked as well as it did was very surprising to us and quite unexpected.

This Affidavit is made with the knowledge that the United States Patent Office will rely on information provided therein, and that willful false statements are punishable by fine or imprisonment or both, under §101 of Title 18 of the United States Code, and

that such willful false statements may jeopardize the validity of the application at bar or any patent issuing thereon.



THOMAS MIKUS